Chapter 11

Optical Instruments

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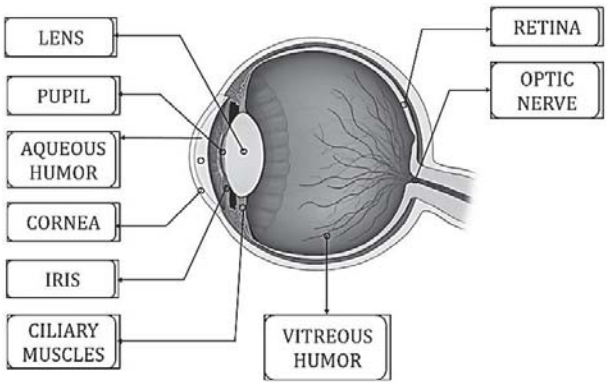
HUMAN EYE AND SIMPLE MICROSCOPE

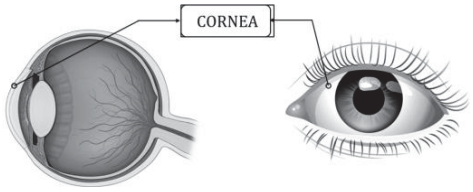
Human Eye and its functioning

We can consider the human eye to be roughly spherical with a diameter of 2.5 cm.

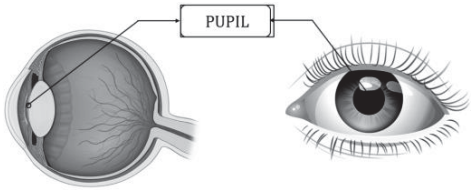


Cornea

It constitutes the outermost transparent layer of the eye.
It bends the incoming light from the surroundings to converge on the retina.



Pupil

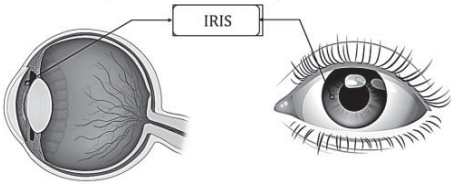


The pupil expands and contracts to regulate the quantity of light entering the eye.
It functions similarly to a camera aperture.

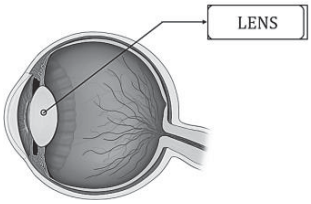
Dilated Pupil Constricted Pupil

Iris

It is the pigment responsible for the eye's coloration. The primary role of the iris is to adjust the pupil's diameter based on the brightness of the light source.

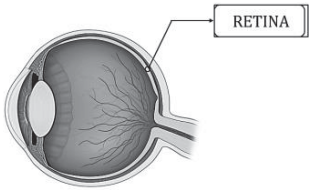


Lens



The lens is a clear refractive structure that assists in directing light rays onto the retina.
It is a biconvex lens present in our eye.
The focal length of the lens is adjustable.

Retina



It's a delicate tissue layer that covers the inner back of the eye.
It detects light and generates electrical signals, which are then transmitted through the optic nerve to the brain.
The retina is where the image is formed.

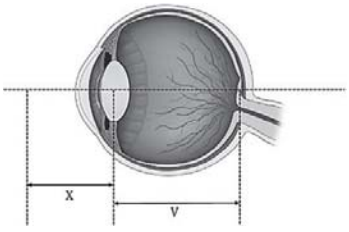
Retina

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

For human eye, v = constant
$u = -x$

$$\frac{1}{v}+\frac{1}{x}=\frac{1}{f}$$

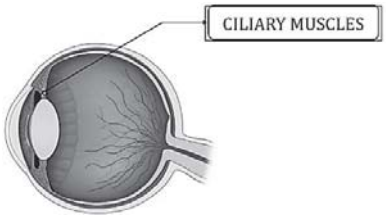
Given that v remains constant, as the object distance varies, the focal length of the lens must adjust for the image to be formed on the retina.



Ciliary Muscles

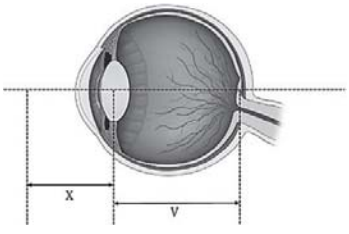
$$\frac{1}{f}=(n-1)\left(\frac{2}{R}\right)$$

In order to alter the value of f, the radius of curvature R of the lens needs to be adjusted.
The ciliary muscles are tasked with modifying the lens's shape to adjust the focal length of our eyes.
This phenomenon is referred to as accommodation.

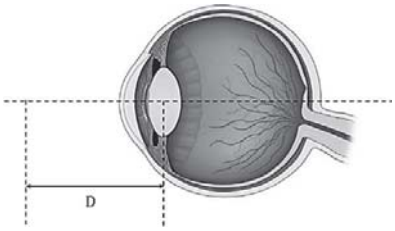


$$\frac{1}{v}-\frac{1}{u}=(n-1)\left(\frac{2}{R}\right)$$

Let the object is being brought from ∞, therefore, *x* decreases.
This signifies that as the object is brought nearer to the eyes, the ciliary muscles contract, causing stress on the lens.
Observing distant objects is less strenuous for the eyes (ciliary muscles) compared to nearby objects.



Least Distance Of Distinct Vision



The minimum distance at which the lens can focus light on the retina is termed as the minimum distance of distinct vision.
D is 15 cm for the adults and 40 cm for the old people.
The average value of D is standardized to 25 cm.

Ex. Suppose the seven colors (VIBGYOR) are kept at equal distance from our eye. Which color strains our eye (ciliary muscles) the least?

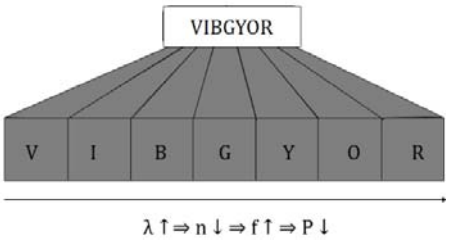
Sol. From Cauchy's formula,

$$n = a + b/\lambda^2$$

As the wavelength of flight (λ) increase refractive index (n) decrease.

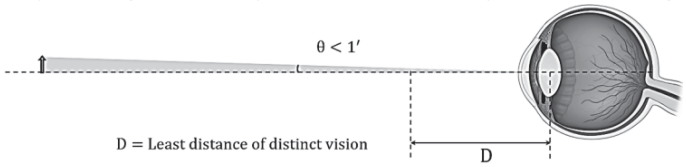
$$\frac{1}{f} = (n-1)\left(\frac{2}{R}\right)$$

From the above equation, with decrease in n, focal length (f) increases and hence, power decreases.
Therefore, red color strains our eyes the least.
Yellow color gives the most sensation to our eyes.

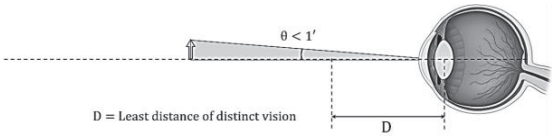


Visibility Of An Eye

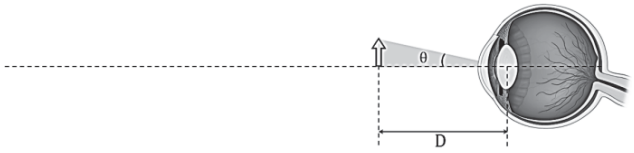
As the object is brought closer to the eyes, the angle it makes with our eyes continues to increase. Our eyes have a limitation such that if the angle formed by the object with our eyes is less than 1 minute, the object cannot be seen distinctly.
However, the object will remain invisible if its distance from the eyes is less than D.
This implies that for an object to be seen, it must be positioned at a distance greater than D. However, for clear visibility, the angle formed by the object with the eyes should be larger than 1 minute.



If $\theta > 1'$ At a distance of D, the object will be both visible and can be seen distinctly by the eye.
If not, then beyond this point, the ability of the ciliary muscles to adjust the focal length becomes limited.



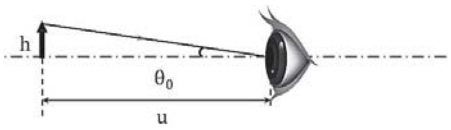
In such instances, a simple microscope is employed. In this microscope, the object is positioned between the focus and the pole of the lens, which is closer to the eye than D. However, the image is formed at a distance exceeding the minimum distance of distinct vision. Consequently, the object becomes distinctly visible to the eyes.



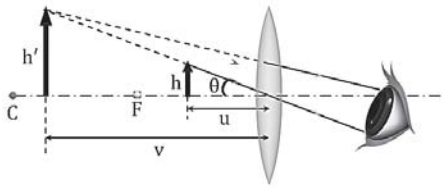
Simple Microscope

Magnifying Power

θ_0 This refers to the maximum angle attainable by the unaided eye. So, if $\theta > \theta_0$, The object can be perceived with greater clarity.



Magnifying power $= \frac{\theta}{\theta_0}$



As, θ and θ_0 are small

$\tan\theta_0 = \frac{h}{D} \approx \theta_0$ and $\tan\theta = \frac{h}{u} \approx \theta$

Magnifying power $= \frac{\theta}{\theta_0} = \frac{h/u}{h/D} = \frac{D}{u}$

For image to be seen properly, v should be b/w D and ∞.

Let u and v be the magnitude of object and image distance from the lens respectively

$$u = -u$$

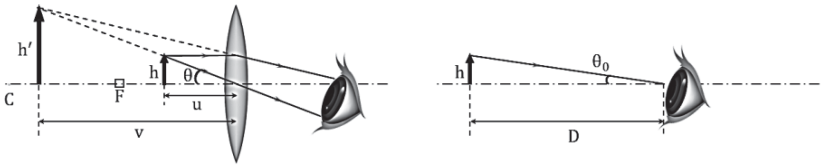
$$v = -v$$

$$\frac{1}{-v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{u} = \left[\frac{1}{f} + \frac{1}{v}\right]$$

Magnifying power, $M \cdot P = D\left[\frac{1}{f} + \frac{1}{V}\right]$

The ratio of the angle formed by the image on the eye to the angle formed by the object on the eye when positioned at the minimum distance of distinct vision.

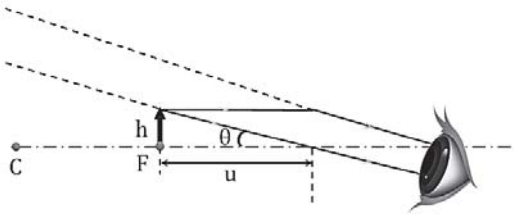
$$M.P. = \frac{D}{u}$$



Simple Microscope

Minimum Magnifying Power

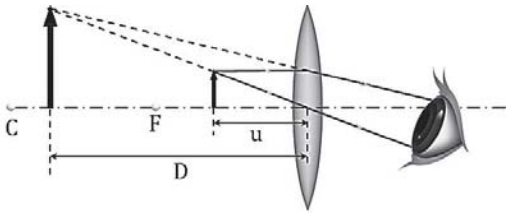
$v = \infty \Rightarrow u = f$



Minimum $M \cdot P. = \frac{D}{f}$

Maximum Magnifying Power

$v = D$



Maximum M.P. $= 1 + \frac{D}{f}$

Note: In a high-quality microscope, both the focal length and the aperture are minimized. Practically, it is not possible to reduce the focal length and aperture beyond a limit.

Ex. Find out the maximum and minimum magnifying power for a simple microscope of focal length 10 cm.

Sol. We know, Minimum M. P. $= \frac{D}{f}$ And, Maximum M. P. $= 1 + \frac{D}{f}$

Minimum M. P. $= \frac{D}{f} = \frac{25}{10} = 2.5$

Maximum M.P. $= 1 + \frac{D}{f} = 1 + \frac{25}{10} = 3.5$

Maximum M.P. $= 2.5$

Minimum M.P. $= 3.5$